DESCRIPTION OF A TYPICAL QUEENSLAND LAGOON.

(The Enoggera Reservoir, near Brisbane)

With Methods of rendering the Water fit for a Town Supply.

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Before commencing this paper and in order to prevent misunderstanding, I would like to state that I claim to be neither a Biologist—in the sense in which the term is used in connection with water—nor yet a Bacteriologist, consequently, in the descriptions and lists of the biological contents of the water which accompany this paper I have confined myself to the enumeration of the genera only, as the determination of the species is, as all know, a task which may only be successfully accomplished by experts who have made a life study of the subject. Similarly, in the department of Bacteriology, I have confined myself entirely to quantitative estimations.

The lagoon under consideration, which is situated near Brisbane, is an artificial one, and was formed by throwing an embankment across the bed of a creek, the upper waters of which it receives. It has been in existence for nearly forty years. Its watershed has an area of 8,295 acres, for the most part heavily timbered, and covered in some places with fairly dense undergrowth.

The catchment area is not fenced, but the lagoon itself is surrounded by a fence placed at a distance of 1 chain from the water's edge. There are practically no human habitations on the watershed, but cattle roam all over it at will.

The banks of the lagoon are cleared of timber for a distance of about 8 chains from the water's edge. There are several tributary creeks feeding the lagoon, but only two of any size.

The area of the lagoon when full, is 186 acres, of which about one-third consists of shallows less than 13 feet deep at high water, that is, when the lagoon is full.

The greatest depth of water is 55 feet, and the estimated total capacity is 1,000,000,000 gallons.

The lagoon contains abundant growths of common water weeds which Mr. Bailey, the Colonial Botanist, has been good enough to identify, and a list of which will be found in the Appendix I to this paper. Many of these weeds die, and rise to the surface whenever any considerable and sudden rise of water takes place in the lagoon. Some of these plants are undoubtedly responsible for a proportion of the colour and odour of the water. Mr. G. C. Whipple, in his work on the "Microscopy of Drinking Water," states that Myriophyllum, of which there is abundant growth in this lagoon, "possesses a natural odour that is strongly vegetable, and at times almost fishy," this odour is imparted to the water whenever the plants die or are crushed and broken. I have myself observed this, and I have also found this plant to cause a sensible increase in the colour of water in which it was placed.

There is practically no flow of water in the creeks feeding the lagoon except after heavy rain. There are many pools more or less deep in the bed of the main creek in which abundant growths of Spirogyra, etc., exist after dry weather has continued for a short length of time. These growths are washed into the lagoon whenever any flow of water takes place in the creek.

The average total rainfall at the lake per annum, for the past five years, was 33.93 inches. (For 1904-5 rainfall see Appendix II.)

The water discharged into the lagoon by the creeks is, for the first day or so after heavy rain, highly charged with organic matter evidently of vegetable origin, and is also highly coloured, but after flowing for some little time it gradually improves in quality until, having run for, in some cases four days, the creek water is in some respects purer than the bulk of the water contained in the lagoon. (Appendix III.)

In a lake of this type one of the most important factors in connection with its biological and chemical composition which we have occasion to enquire into is the period or periods during which the water in the lake is in a state of stagnation or circulation, these periods depend almost entirely on the temperature of the water throughout its depth at different times of the year. In colder climates there may be two periods of circulation of the water in a lake, but in a climate like ours there can be only one unless indeed, the lake be over 200 feet deep when stagnation would probably be permanent.

During the months between July and May, there is a difference of from 5 to 20 degrees Fahrenheit between the temperatures of the surface and bottom water in this lagoon, it is to be expected therefore that during that period the bottom layers of water are certain to remain at the bottom by virtue of their greater density. This period is termed the "period of stagnation." It causes several changes to take place in the character of the water at the bottom of the lagoon. The most conspicuous change is that of colour. Whilst the colouring matter in the water remaining at the surface is bleached by the action of the sun's rays, that at the bottom grows gradually darker until, near the close of the stagnation period it has a decided opalescent turbidity and a rich brown colour, which deepens after being drawn to the surface. This colour is probably due to the presence of iron in the water, as well as to the sedimentation of the organic matter, which is much increased in the bottom layers during this period. The oxygen dissolved in the bottom water disappears during stagnation, owing to its absorption by the organic matter, putrefaction takes place, and the water acquires an offensive odour, in which the familiar sulphuretted hydrogen plays a large part. The effect of stagnation on the microscopic organisms is no less remarkable, owing to the absence of oxygen and light little life exists at greater depths than 20 feet, but the water at the bottom acquires an abundant supply of food material, both organic and inorganic, suitable for microscopic life.

Towards the end of May, however, on the approach of colder weather, the decrease in temperature at the surface increases the density of the water there, gradually leading to a complete vertical circulation of the water in the lagoon, until, about the middle of June, the temperature of the water is practically the same throughout all depths. About that time stagnation once more commences, and continues throughout the remainder of the year, until May comes round once more, when the process is repeated. (Appendices IV and XIII.)

During the period of circulation the character of the water at the various depths is completely changed, the colour of the water becomes uniform throughout all depths, consequently the colour at the surface increases; indeed I have found it on one occasion, *viz.*, 5th June, 1905, to be slightly darker at the surface than at the bottom; dissolved oxygen is now found at all depths, and the microscopic organisms are evenly distributed, whilst the food material before mentioned is carried to the upper regions where, with light and oxygen, the organisms are able to utilise it.

The following figures illustrate in a striking manner the difference between the condition of the water during stagnation, and during the period of circulation:

	During the Stagnation Period.			During the Circulation Period.		
	May 19th, 1905. Colour Units.		May 5th, 1905 Dissolved Oxygen.	June 5th, 1905. Colour Units.		June 20, 1905 Dissolved Oxygen.
	Red.	Yellow.	per cent. of Saturation.	Red.	Yellow.	per cent. of Saturation.
Surface	1.9	6.5	58.5	3.0	10.0	103.0
Thirty Feet			nil.			60.8
Bottom (45ft)	42.0	32.0		2.7	8.0	

(Colour determined by Lovibond Tintometer.)

It will be seen therefore that in this lagoon, containing as it does an excessive amount of organic matter, the occurence of these phenomena produces no improvement in the quality of the water, and is in fact a large factor in the process of deterioration. Before leaving this subject, however, on which one might talk all night and concerning which much has been written, I might remark that stagnation is productive of no disagreeable effects when the lake bottom contains no organic matter, and that it does not occur in shallower lakes such as those only 10 to 15 feet deep, for in such lakes thermal stratification hardly exists.

Quantitative estimations of the bacteria in this water have been made at irregular intervals since November, 1904. As usual with waters of this class the numbers are comparatively small, averaging about 400 per cubic centimeter when grown on neutral agar medium. (Appendix V.)

Sufficient analyses have not been made to show the seasonal variations in the different micro-organisms in this lagoon water, it is noted, however. that the diatom Synedra, and the chlorophyll alga Protococcus are always more plentiful after rain.

Comparatively large areas of a scum consisting for the most part of Anabœna, Protococcus and Oscillaria float on the surface of the lagoon during the summer months, and are found generally near the edges where they have been blown by the prevailing wind. The protozoa Peridinium is also very plentiful. and is found in large numbers associated with the scum before mentioned.

A micro-organism which I consider to be a variety of Protococcus is the predominating organism in this lagoon , it may be seen at all times of the year. but particularly in summer and after heavy rains, distributed throughout the surface as a bright green powder of irregularly shaped particles. This organism, which I have not yet been able to identify satisfactorily, but specimens of which Mr. Bailey has kindly forwarded to Professor Borge, in Germany, for determination, is most obnoxious when plentiful ; it has not yet given trouble in the lagoon under discussion, but in a similar and not far distant lagoon it became, some months ago, so bad that the water was of a bright green colour throughout, and at the edges in some places the organism was so plentiful as to impart to the water the consistency of mud. The odour given off by this organism was so bad that a workman, the nature of whose employment required that he reside near the lake. asked for and was actually supplied with a considerable quantity of disinfectant for use around his residence whilst the lake was being emptied.

Spirogyra grows abundantly during the summer in the shallow water round the edges of the lake.

When this lagoon water is passed through iron pipes under low pressure. abundant growths of the Bryozoa, Plumatella soon become attached to the interior surface of the pipes. It is found in active growth and decay nearly all the year round, but about the autumn decay is usually more marked, whilst is is less noticeable in the winter. The growth extends at times for about 5 inches from the iron to which it is attached, forming a dense mat in the lower 2 inches. Statoblasts are found in the Plumatella all the year round, but are most plentiful when the decay is most marked. Freshwater sponge and Hydra are always found associated with the Plumatella. The smell from this Bryozoa and Sponge when in process of decay is most offensive, and is a serious cause of odour in the water when it is passed through iron pipes. I might here remark that these organisms will not grow in the water which is produced in the methods about to be described. (Appendices VI. and XII.)

I find it difficult, in fact almost impossible to describe satisfactorily the odour of this water ; it may be described in a vague manner as a mixture of Vegetable—Salt Marshy—Grassy and Fishy—each item predominating at different times of the year. During long periods of drought the odour is almost absent, and it is I think most offensive when it has been in contact with decaying Plumatella.

As regards chemical compostion I find the water of this lagoon to be comparatively constant throughout the year, a list which I have prepared giving the monthly averages of weekly analyses of samples drawn 5 feet below the surface since May, 1904, shows the organic matter as indicated by Albuminoid Ammonia determination, to have been highest in March, when it was averaged .367 parts per million for the month, the lowest figure obtained being for January, when it averaged .260 p.p.m. Nitrates were absent throughout the year, whilst Nitrites were only occasionally searched for, but never found present. (Appendix VII.)

In colour the samples varied considerably, the highest figures being obtained in May and June during the period of of vertical circulation in the lagoon, the variation being from 52 on the platinum scale in June, 1904, to 20 on the same scale in January, 1905. The Chlorine figure was practically constant throughout the year, being about 34 parts per million or roughly 2.4 grains per gallon. The hardness of this water is very low, being about 3 degrees on Clarke's scale.

In spite of the comparatively large amount of organic matter which it contains this water is not by any means an "acid" water, except by virtue of its "Free Carbonic Acid," that is to say it contains no acidity due to "organic" acids.

In no case would any of the samples obtained from the lagoon have been considered suitable for a town supply if only on account of the amount of organic matter indicated by the figures quoted.

Having thus briefly reviewed the Physical, Biological and Chemical conditions obtaining in this lagoon, I now come to the second portion of my paper, *viz.*, the description of methods of rendering this water fit for a town supply.

Before commencing on this subject I would like to make one more disclaimer. I have had no opportunity of testing the processes about to be described on anything like a large scale, the results having been obtained on small filters, the largest being 76 square feet in area, and yielding nearly 5,000 gallons of filtrate per 24 hours. Nevertheless, the greatest care has been taken in every case to imitate as closely as possible the conditions which would exist were the filter an acre or more in area, and I am confident that the results obtained on this experimental scale closely approximate to those which would be obtained on the larger scale required for a town supply.

It may be well at this stage to consider briefly the various methods in use for securing a pure supply of water from a source of this nature.

First there is the method sometimes adopted of cleaning the watershed and also the lagoon which contains the water collected from it. This is a most desireable proceeding, though there exists some doubt as to the permanency of the benefits to be derived from cleansing the bottoms of such lakes, but time does not permit of going into the question in detail here.

With smaller lakes it is sometimes the practice in warm climates to roof them over entirely, thus preventing the growth of the various forms of microscopic life which are responsible for a large portion of the obnoxious odours and tastes in the water. Water stored in this fashion, collected of course from a clean watershed, but which before roofing the lake has been a constant trouble on account of vegetable growths is said to remain "clear and pure as crystal, and nearly as pure as distilled water;" this statement is made after 30 years experience by Mr. C. Eliot, City Superintendent of the Spring Valley Waterworks, of San Francisco, in a letter to the Committee of the American Waterworks Association, on Animal and Vegetable Growths affecting water supplies, 1890. When a reservoir was too large to permit of the construction of a roof over it, the same object is said to have been accomplished by the construction of a large raft which floated on the surface of the water, and from under the centre of which the supply was drawn.

Of other methods of purifying lake waters *in situ* the most important is that devised by Dr. G. T. Moore, and which is reported to have been successfully used in several lakes in America. The method consists essentially in the addition of sulphate of copper to the water in the lake with the object of destroying the micro-organisms contained therein. The method will be dealt with later on in this paper.

In nearly all other methods the purification of the water is effected outside the lagoon.

These methods comprise—Settlement in covered basins, either by simple subsidence or subsidence aided by coagulants such as lime or alum, and with or without the use of screens. Sterilization by distillation, which is as a rule too costly to be used in conneetion with a city supply, and lastly Filtration.

Filtration is the most important of these methods and the most generally used. It may be divided into two great sections—Plain Sand Filtration and Mechanical Filtration.

The first section includes all sand filters, both continuous and intermittent in action, which depend for their efficacy on the power of the sand alone to retain and remove suspended matter in the water, and on oxidation effected by the life processes of bacteria. These filters are generally operated at slow rates, such as from 1½ to 5 million gallons per acre per day.

In the second section, I include all those methods of filtration in which sand filters are used in conjunction with coagulants and all filter presses of canvas or other porous material such as the fused mixture of glass and sand, used in the Fischer Plaque filter. Filters under this section are nearly always operated at extremely rapid rates amounting in some cases to 130,000,000 gallons per acre per 24 hours.

There are methods of filtration which do not come under either of these heads, but all the more important processes at present in use on a large scale are included.

As I have already indicated, the water of this lagoon is objectionable for a town supply owing to its appearance, colour, smell and taste, but apart from these aesthetic considerations, water of this description is to some people positively harmful, causing when imbibed in any quantity various stomachic complaints.

The purification of waters of this class is generally consiedred to be one of the difficult problems which Waterworks Engineers and Chemists have to deal with.

In the experimental purification of this water, the following methods have been tested :—

(*a*) Plain continuous filtration in filters constructed entirely of sand, with, of course, underdrains, and in filters whose sections consist of layers of sand, ashes and crushed quartz of various grades.

(*b*) Plain intermittent sand filtration.

(*c*) Mechanical filtration, with lime and alum as coagalants.

(*d*) The Anderson Process, which comes under my heading of Mechanical Filtration.

A method of water purification has been tried which, strictly speaking comes under neither of the heads mentioned, but which may for practical purposes be described as slow, downward, intermittent filtration. This ingenious process was suggested by Mr. Arthur Morry, of this City, who was at that time District Supervisor of Public Works, and in that capacity devoted a considerable amount of time and thought to the subject of water purification. A combination of this process and ordinary sand filtration was also experimented with. One more process has been tested, namely, Dr. Moore's method of removing Algae and Bacteria from water supplies by means of copper sulphate.

Continuous Sand Filtration.

Although no less than five different filters have been used in this investigation, it is sufficient for the end in view to consider in anything like detail the results obtained from but one of them, a filter whose section is composed entirely of sand. This filter has an area of 25 square feet, and a section as follows :—

Fine sand at top of bed (effective size ·335 *m.ms.*)	41 inches
Underdrains composed of various grades of gravel	12 ,,
Total depth of material	53 ,,

The depth of water over the sand was 41 inches, whilst the maximum loss of head was 91 inches. The method of operating the filter is as follows :—It is fed from below with filtered water until it attains a depth of about 6 inches above the surface of the sand, unfiltered water is then fed on to the bed from above, and filtration commenced as soon as the water in the filter is 2 feet over the sand. For the greater portion of the time during which this filter was in operation, water was discharged on to the bed through an aerator, which divided it into a comparatively fine spray. The filter was allowed to run until it became so choked with organic matter that a "head" or pressure of 7 feet 10 inches was necessary to force the water through the sand at the required rate. The feed water was then turned off, the sand allowed to drain, and the surface removed for a depth of about half-an-inch. The filter was then restarted as before detailed. The period between the times when scraping the surface to remove clogging becomes necessary is termed a "run," and varies according to the nature of the applied water. The average length of run for this filter during the time it was in operation, was over 70 days, showing clearly that the sand used for the filter bed was not by any means too fine, as this is a comparatively long run for a filter of this type. This filter remained in operation for 183 days, the average rate of filtration maintained throughout that period was exactly 2 million gallons per acre per 24 hours. Chemical and Physical analyses of the unfiltered water and effluent were made weekly, and a monthly average of the percentage reduction of organic matter and colour, is given in Appendix VIII.

The average reduction of organic matter, as shown by the Albuminoid Ammonia determinations throughout the whole period of operation was more than one-half, whilst the reduction in colour was 66 per cent. of the yellow, and 93¼ per cent. of the red units determined by means of the Lovibond Tintometer. The number of bacteria per cubic centimeter in thé effluent and unfiltered water were also determined from time to time, the average result of nine determinations showing 462 per c.c. in the unfiltered water, whilst only 7 per c.c. appeared in the effluent, which is equivalent to a per centage reduction of 98½. Throughout the whole time the appearance of the effluent was good, its taste was excellent, no odour was noticeable, and it was to the ordinary observer practically colourless. The sand used in this filter was of poor quality, being the result of recent decomposition of granite, it was very friable and exceedingly difficult to clean, and even when washed with apparent thoroughness still contained a good deal of organic matter. Had better sand, such as that obtained from the Brisbane River bed been used, the results from this filter would doubtless have been still better.

I have described this filter in preference to the other sand filters mentioned, because it is the most typical of the group. Even better results were obtained from one of these filters in whose section ashes played an important part, but this improvement was proved to be due not to the ashes, but to the finer grade of sand in the surface layer.

The last mentioned filter contained besides cinders and crushed quartz, 12 inches of sand on the surface of the bed, which had an effective size of ·28 m.m.s. The sand used was of superior quality to that in the first-mentioned filter composed entirely of sand, which probably accounts for the better chemical results obtained. The Bacteriological results were however not quite so good, probably on account of the fact that the depth of the sand layer in this filter was less than in the former filter. The length of run or period between scrapings was also not so good as for the sand filter, averaging only 31 days. this was to be expected on account of the finer grade of sand employed.

During the warmer weather and on account of the increased bacterial activity occasioned thereby, it was found that the removal of the organic matter and colour by these filters was much greater than during the colder months of the year. For a similar reason the amount of dissolved oxygen found in the effluents of these filters at the same period was very small, the oxygen in the applied water being practically exhausted before the water reached the outlet of the filter. As the amount of dissolved oxygen in the lagoon water at this time of the year is comparatively low, aerators were fixed at the inlets of both filters. These had the effect of practically saturating the applied water with oxygen, increasing the amount from 75 per cent. of the possible quantity to about 98 per cent. Notwithstanding the increased amount in the applied water, however, the oxygen still continued to be almost entirely exhausted in its passage through the filters, though a slight increase took place in the amount contained in the effluents.

In order to investigate this phenomenon, arrangements were made whereby samples of water might be drawn from different positions in the sand bed. Several determinations of the number of bacteria and the amount of dissolved oxygen in the water at different depths in the sand were made. It was expected that the rates of decrease of bacteria and dissolved oxygen would be somewhat similar, or that the decrease in oxygen would cease in those portions of the filter which contained practically no bacteria; this was expected on the assumption that the decrease in the amount of oxygen dissolved was entirely due to its consumption by the bacteria in the process of oxidation of the organic matter in the water.

It was found that the bacteria were practically all removed in the upper 6 inches of the sand, but that whilst about one-half of the total absorption of oxygen by the filter took place in the first 6 inches, the amount continued to decrease at a fairly regular rate throughout the remaining depths of sand where the water at the same time contained practically no bacteria I am not able to satisfactorily explain this phenomenon, but intend if possible to investigate further.

Intermittent Sand Filtration.

Following a line of thought suggested by the last mentioned experiments, an intermittent filter was constructed with a view to testing the effect of more efficiently aerating the sand bed. The filter is 76 square feet in area, and is constructed on the lines of the City filter at Lawrence, Massachusetts, in the United States of America. The bed of this filter is composed of 5 feet of sand of an effective size of ·27 m.m.s., placed over underdrains of gravel and brick. The method of working is as follows :—Water is fed on to the filter bed by means of a gutter placed along the centre of the filter 2 inches above the surface of the sand, no attempt is made to obtain any depth of water over the surface of the sand bed, so that the water flows almost directly through it in such a manner as to leave the greater portion of the surface dry. By this means the growth of algae on the surface of the sand which takes place in ordinary continuous sand filters is avoided, and the periods between the times when scraping becomes necessary are in consequence greatly increased. No water is fed on to the filter for a certain portion of every 24 hours, during which time the filter is allowed to drain, and in this manner the sand bed is completely aerated every 24 hours. Two different periods of rest have been tried for considerable lengths of time in this filter, namely 8 hours and 4 hours, the former period, 8 hours, appears so far to give the best results. The cessation of work for such a large portion of the time naturally necessitates a greater rate of flow through the filter than is the case with ordinary sand filters, in order to accomplish the same amount of work for the 24 hours. Nevertheless, in spite of the increased rate, the reduction of colour and organic matter has been excellent, and the average reduction effected by this filter when working with a daily rest of 8 hours is distinctly better than that effected by any of the ordinary sand filters. The Bacteriological results from this filter are, however, not so good as those obtained from the ordinary sand filters, the average reduction effected being about 74 per cent. (Appendix IX.)

We now come to the consideration of results obtained from filters of the type designed by Mr. Morry, which he describes as "Biological Oxidising Beds." Mr. Morry states that the idea of their construction was suggested by the "Ducat" and "Stoddart" beds used in sewage purification, and which are built up above the ground. In brief the beds are composed of about 6 feet in depth of gravel, or coal, in varying grades ; in some of the filters these beds are so constructed as to admit of side aeration, but the feature which is common to all is the method of delivering the unfiltered water on to the bed of the filter. This is done through an intermitter from which the water is discharged at intervals into the basin of a revolving sprinkler running on ball bearings, which distributes it regularly and evenly over the surface of the filter bed, through which it slowly percolates and flows into underdrains which lead into a small receiving vessel. The object of this method of discharging the effluent is to insure the thorough aeration of the water in its passage through the filters. That this has been effected is proved by the fact that even in the warmest weather the effluents from all but one of these filters contained over 95 per cent. of dissolved oxygen, and it has been proved that this aeration is chiefly produced during the passage of the water through the bed of the filter itself. Altogether 8 filters of this type were experimented with; they may be divided into two classes, namely, those in which sand forms a portion of the filter bed and those in which the filter bed consists entirely of gravel.

Two beds composed partly of sand were tried. In each of these the surface layer was composed of one foot in depth of sand, which was also of the same grade in each case. In one, the remainder of the filter bed was composed of coal in four layers of different grades, the coarsest with material ½ inch in diameter, being at the bottom, making the total depth of material 6 feet. In the other filter the remainder of the bed is composed of gravel in four layers, which are identical in grade and depth with those in the coal filter. The coal filter is fitted with means of securing both side and bottom aeration, whilst no provision for such aeration is made in the gravel bed. In consequence of this the amount of dissolved oxygen in the effluent from the coal bed is much greater than in the gravel bed effluent. The reduction of colour and organic matter however, was found to be much better in the gravel than in the coal bed filter, whilst the bacterial purification was the same in each, the reduction effected being about 92 per cent. The effluent from this gravel and sand bed filter was in every way excellent, and the average results are equal to the best results obtained by sand filtration.

The beds in which gravel alone was used, though effecting a remarkable reduction in the organic matter and colour of the water, are open to two objections, firstly—They take a considerable time to properly mature or get in working order, and secondly—Even when matured, their effluents though bright and sparkling and in every other way desireable, always contain a slight amount of matter in suspension, also as might be expected the reduction in the numbers of bacteria is comparatively poor.

The consideration of the foregoing circumstances led to the conclusion that a combination consisting of a bed of this type worked in conjunction with an ordinary sand filter would give excellent results ; the rapid passage of the water through the gravel bed would it was thought effect a partial purification of the water without removing all the suspended matter, at the same time aerating it, and thus rendering it in every way more amenable to treatment by the sand filter. It was decided to try the experiment. A small square gravel filter of the Morry type was constructed with an effective area of 12 square feet and a depth of 3 feet, a small sand filter was also constructed, having an area of 18 square feet, and composed of 2 feet of fine sand. These two filters were arranged so that the sand filter might be conveniently fed with the effluent from the Morry filter. The sand filter was worked in the usual way, but with a depth of only 11 inches of water over the sand. Although only a poor quality of sand was used in this filter, the results of the analyses of its effluent have fully realised the expectations before mentioned. When the combination was worked at a rate which gave a yield of water from the combined areas equal to that obtained from a similar area of the ordinary sand filters, the results obtained showed a reduction of organic matter, which was a distinct improvement on the results obtained from the best of the sand filters, and whilst the reduction of the numbers of bacteria was equally good, the amount of dissolved oxygen in the effluent averaged 66 per cent. of the possible quantity during a period in which the oxygen in the ordinary sand filter effluents averaged only 10 per cent.

Having considered the results obtained by filtration of the water without the assistance of coagulants, the next method for consideration is that of Mechanical Filtration.

The main object of mechanical filtration is to purify large volumes of water with a small amount of filtering material. In order to effectively do this the addition of a coagulant is generally necessary in order to remove a portion of the polluting matter before filtration, and to quickly form on the surface of the sand in the filter a coagulum which takes the place of the natural film produced by subsidence of suspended matter and bacterial action on the surface of a plain sand filter. This form of filtration is only " mechanical " in connection with the arrangements for agitating the sand during the frequent cleansing necessary, and for the regular dosing of the applied water with the solutions of coagulant

Experiments conducted with the water of our lagoon showed the best proportion of coalguants to be 1 grain per gallon of alum and 4½ grains per gallon of lime. Four hours settlement after adding the coagulants but prior to filtration was also found to be necessary.

Time does not permit of a detailed description of the experiments conducted with this process, which extended over a period of six months, I must content myself with stating that very excellent results were obtained throughout the experiments.

For purposes of comparison, I have constructed tables showing the average composition of the effluent of the mechanical filter for a period of three months, during which the best results were obtained at a rate of filtration equal to 104 million gallons per acre per day. For purposes of comparison, I have also calculated the average composition of the effluent from the intermittent plain sand filter before described during a similar period of three months, whilst operating at an average rate per day of 2.23 million gallons per acre, and a rest interval of 8 hours in every 24. I have also calculated in each case the reduction of organic matter effected in the same period. This shows the percentage reduction of organic matter, as indicated by the albuminoid ammonia figures to be roughly 58 in the case of the intermittent plain sand filter, against 56 in the case of the mechanical filter, although the average albuminoid ammonia contents of the plain sand filter effluent was .136 parts per million, as against .123 parts per million in the mechanical filter. It is true also that the best result obtained by mechanical filtration was better than the best result obtained from the plain intermittent sand filter, but in view of the decided predjudice which exists against the use of alum in connection with the purification of a water supply, whether this predjudice is justified or not, I venture to assert that the comparison is all in favour of plain sand filtration, especially when it is considered that the average results compared are not the best results obtained from plain sand filtration, though unfortunately I have no better figures available from observations conducted throughout a similar period. (Appendix X.)

The next method for consideration is Anderson's Process. This process comes under my heading of Mechanical Filtration, though it has not the objectionable feature of the method just described, namely the use of alum as a coagulant. The process in brief is as follows:—Metallic iron, in the form of cast iron borings or steel punchings is placed in an iron cylinder, through which the water passes on its way to the sand filters. This cylinder is so arranged that by its slow rotation the iron is continually lifted and showered down through the water, which is being passed at a moderate speed through the cylinder. Air also is introduced. By means of this contrivance a small quantity of iron is dissolved in the water through the agency of the carbonic acid contained therein. This iron is dissolved in the form of ferrous carbonate, which on coming into contact with the air is oxidised and precipitated as ferric hydrate in particles more or less coarse, according to the nature of the water. This precipitate settles rapidly, carrying down with it and possibly oxidising the organic matter in the water, and at the same time removing the bacteria also. Subsequently the presence of this flocculent precipitate in the water permits of its rapid and efficient filtration through a simple sand filter.

The use of this process for the purification of our lagoon was suggested to me by Mr. Parkinson, a well-known civil engineer of this city, who was kind enough to lend me a copy of the proceedings of the Institution of Civil Engineers containing a paper by Messrs. Chadwick and Blount, on the results of their experience with this method as a means of purifying the waters of lakes similar to ours in Mauritius and South Africa. The results described in that paper were so very good that it was determined to try the method on our lagoon water.

I regret to say that I am unable to describe the results of experiments with this method on anything but a laboratory scale, but the results thus simply obtained are so very excellent as to warrant the assumption that if tried on a larger scale, an effluent would be obtained which would easily excel the best results obtained by any of the methods I have just described, at the same time requiring a very much smaller area of sand bed, on account of the much greater rapidity with which the water may be efficiently filtered after treatment in this manner. (Appendix XI.)

One more system of water purification remains to be mentioned before I conclude, namely Dr. Moore's method of destroying and preventing the growth of algae and bacteria in water supplies.

The numerous experiments with this method and our lagoon water, which continued without cessation during a period of three months, thoroughly confirm the results obtained in America in similar lakes by Dr. Moore, or under his direction.

The method used for the distribution of copper sulphate throughout the lake is to tow it in coarse bags behind boats, in this manner it is stated that 100 lbs. of the salt can be distributed in 1 hour.

The toxicity of copper sulphate is so great that on one occasion when experimenting with so small a proportion of the salt as 1 to 8 million of lagoon water, only a few protozoa remained in the water after treatment, whilst untreated water which had been standing under exactly similar conditions, contained at the end of the experiment as many as 1.320 organisms per cubic centimeter.

The satisfactory fact was also noted that the organisms which are most objectionable and most plentiful in this lagoon, showed the greatest sensitivity to the sulphate of copper. From the results of the experiments, I think it is safe to conclude that a strength of solution of 1 part of copper sulphate to from 8 to 10 million parts of water is sufficiently strong to effectively remove the obnoxious algae from this water, this proportion stated in other terms is equivalent to 1lb. of copper sulphate in every 800,000 to 1,000,000 gallons of water. I consider also, that if this salt is added to the lagoon water during the stagnation period before mentioned, a still smaller amount of the salt would be necessary on account of the fact that organisms exist to any great extent during that period only in the upper 15 feet of water, whilst it is probable that the stratification of the water by reason of its varying density would help to maintain the solution in the upper layers of a sufficient strength and for a sufficiently long period to enable it to do its work among the algae; and it is to be remembered also that in the surface layers of water where the algae are most abundant, the solution will in any case owing to the method of application, be for a short period much stronger than one to eight million.

My experiments also proved that when solutions of the strength named were used, no copper could be detected in the water three days after its addition, although the test used would easily have detected the presence of 1 part of copper sulphate in 25 million parts of water. As this proportion is equivalent to 1 part of metallic copper in 100 million parts of water, it may be considered I think that all the copper is eliminated by precipitation.

In the majority of these experiments with copper sulphate, 4½ gallons of water were used, the containing vessel being glass in nearly every case. Small fish were invariably present, and in no case suffered any apparent inconvenience.

It is impossible here to go into the results obtained in these experiments in anything like detail, and it is sufficient to state that the results indicate that the method could be successfully applied to a water of the type under consideration, nevertheless although the copper sulphate treatment is a most valuable remedy for the unpleasant odours and tastes, and might be advantageously applied where no other method of purification exists, or in conjunction with other methods, it does not remove the colour and dissolved organic matter, and only removes one of the causes of colour and organic contamination, consequently it cannot be said to remove the necessity for filtration.

In conclusion I may state that nearly every one of the methods I have described for the purification of this lagoon water yields a product which would be received with delight if delivered to consumers by the pipes of any water system in Australia. Not only is the purified lagoon water excellent for drinking purposes, but it is also eminently suitable for other uses; its softness and freedom from colour rendering it especially desirable for laundry work and steam raising.

It is evident from the results of these investigations that the purification of waters of this type is not by any means the impossibility which tradition has taught us to imagine it.

In the course of these investigations, I have frequently found it necessary to obtain the advice of several of my friends, better versed than myself in various phases of this subject, and I seize this opportunity of expressing my gratitude to these and all others who have rendered me assistance.

Appendix I.

LIST OF AQUATIC PLANTS IN LAGOON.

Names Supplied by F. M. Bailey, F.L.S., Colonial Botanist.

Utricularia flexuosa.
Hydrilla verticillata.
Myriophyllum verrucosum.
Myriophyllum variaefolium.
Jussiaea repens.
Ottelia ovalifolia.
Marsilea Brownii.
Eclipta alba.
Cyperus exaltata.
Polygonum lapathifolium.
Polygonum attenuatum.
Limnanthemum indicum.
Nymphæa gigantea.
Nymphæa flava.
Azolla rubra

Appendix II.

RAINFALL AT LAGOON, 1904-1905.

			Inches
Month Ending	June	1904	0.16
	July	,, ...	1.89
	August	,, ...	0.61
	September	,, ...	1.41
	October	,, ...	1.32
	November	,, ...	2.24
	December	,, ...	2.34
	January	1905	9.83
	February	,, ...	3.18
	March	,, ...	2.09
	April	,, ...	5.74
	May	,, ...	1.25
		Yearly total	32.06

Appendix III

CHEMICAL AND PHYSICAL ANALYSES OF MAIN CREEK AND LAGOON WATERS.

	No. of Analysis:			
Parts per Million	No I	No 2	No 3	No 4
Total Solids	150.	185.	114.3	107.1
Total Solids in Suspension	7.2	50.	7.2	7.1
Chlorine	35.7	34.3	33.6	37.1
Free Ammonia ..	.04	.025	trace	.015
Albuminoid (Total) ..	.305	.340	.195	.245
do. do. (in solution)	.235	.295	.185	.205
Oxygen Consumed in 15 Mins. at 90° Fahrenheit	3.40	5.24	3.01	1.38
do. do. in 4 hours	8.07	9.46	6.98	2.72
Nitrogin existing as Nitrates	Nil	Nil	Nil	Nil
Turbidity (Silica Scale) ..	15.0	30.0	10.0	5.00
Odour Warm, Odour is of "decaying vegetable matter"	very strong	strong	decided	very strong
Colour (with Hazen's tubes)	114.	142.0	110.	26.
Colour, Lovibond Tintometer				
Red (Units)	4.4	6.2	3.0	1.0
Yellow ,,	11.2	16.8	9.2	3.7

Analysis, No. 1, 15/1/05.

Water from Main Creek entering lagoon after creek had been running one day in slight flood, rainfall for previous 24 hours 5.37 inches.

Analysis No. 2, 17/1/05.

Water from Main Creek entering lagoon after creek had been running two further days slightly stronger than on 15/1/05. Rainfall for previous 48 hours 0.49 inches.

Analysis, No. 3, 18/1/05.

Water from Main Creek entering lagoon after creek had been running one further day less strongly than on 17/1/05. Rainfall for previous 24 hours 2.3 inches.

Analysis, No. 4, 18/1/05.

Water from lagoon at outlet.

Appendix IV.

TEMPERATURE OF WATER IN THE LAGOON.

Degrees Fahrenheit.

Average Daily Temperature per Month.	1903-1904. Surface.	1903-1904. Bottom.	1904-1905. Surface.	1904-1905. Bottom.
June	58.2	56.5	58.7	58.1
July	57.8	56.8	56.4	54.2
August	59.9	57.1	59.3	55.2
September	65.0	59.9	64.4	56.2
October	69.9	58.0	71.0	57.3
November	73.1	58.9	77.0	58.6
December	79.0	59.9	78.0	59.0
January	78.7	60.6	78.7	59.6
February..	77.2	61.0	78.8	59.2
March	75.9	61.4	77.2	60.5
April	69.8	62.0	72.6	61.0
May	65.6	61.8	65.9	58.2
Maximum temperature for above period ..	83.0	63.5	86	62
Date	21/1/04	May '04	3/1/05	April, '04.
Minimum temperature for above period ..	53.0	55.0	54.0	54.0
Date	16/7/03	June, '03	4/7/05	July, '04.

Appendix V.

TABLE SHOWING THE BACTERIAL CONTENTS OF THE SURFACE LAGOON WATER ON DIFFERENT DATES DURING 1904-1905.

Date of Analysis.		Bacteria per C.C.
28th November, 1904	.. ..	130
5th December, 1904	.. ..	150
12th December, 1904	.. ..	170
19th December, 1904	.. ..	130
2nd February, 1905	.. ..	1100
8th February, 1905	.. ..	375
16th February, 1905	.. ..	350
21st February, 1905	contained scum from surface	270,000
3rd March, 1905	contained scum from surface	8775
8th March, 1905	.. ..	600
30th May, 1905	.. ..	275
15th June, 1905	.. ..	110
23rd June, 1905	.. ..	550
27th June, 1905	.. ..	100
12th July, 1905	.. ..	170

Estimations made in Petri Dishes at Laboratory Temperature.
Medium used 1.5 % Neutral Agar, with Beef Extract.
N.B.—Optimum reaction with this water = Neutral

Appendix VI.

LIST OF MICRO-ORGANISMS, OTHER THAN BACTERIA, FOUND IN THE LAGOON WATER, DURING THE PERIOD APRIL, 1904—JULY, 1905.

DIATOMACEAE :—	*Synedra ulna*, Synedra pulchella, Nitzschia, Navicula, Asterionella, Tabellaria, Cocconeis, Himantidium.
CYANOPHYCEAE :—	*Anabœna*, Glœocapsa, Coelosphaerium, *Microcystis*, Oscillaria, Aphanocapsa, Lyngbya.
SCHIZOMYCETES :—	Crenothrix, Beggiatoa.
CHLOROPHYCEAE :—	*Chlorococcum*, *Protococcus*, *Haematococcus*, Scenedesmus, Coelastrum, Cosmarium, *Palmella*, Pandorina, Raphidium, Staurastrum, Conferva, Desmidium, Closterium, Volvox, Kirchneriella, Micrasterias, Ophiocytium, Pediastrum, Staurogenia, Ulothrix, Xanthidium, *Ankistrodesmus*, Arthrodesmus, Botryococcus, Docidium, Sphaerozosma, Gloeocystis, Dictyosphaerium, Dimorphococcus, Hyalotheca, Penium, *Spirogyra*, Stigeoclonium, Chaetophora, Zygnema, Microspora.
PROTOZOA :—	*Peridinium*, Dinobryon, Ceratium, Cryptomonas, Mallomonas, Vorticella, Chlamydomonas, Coleps, Enchelys, Euglena, Nassula, Paramaecium, Phacus.
ROTIFERA :—	Anuraea, Rotifera, Asplanchna, Diglena, Triarthra, Notholca.
CRUSTACEA :—	*Bosmina*, *Cyclops*, *Daphnia*, Diaptomus, Sida.
OTHER ORGANISMS	*Plumatella*, Arcarina, Anguillula, Hydra, Spongilla.

Those *italicised* occasionally observed in large numbers.

Plumatella, Hydra and Spongilla plentiful on wooden piles in lagoon, and in low pressure lengths of pipe.

APPENDIX VII.

MONTHLY AVERAGE OF WEEKLY ANALYSES OF THE LAGOON WATER DRAWN FIVE FEET BELOW THE SURFACE. MAY, 1904 TO JULY, 1905.

Date. 1904.	Temperature of Water. Deg. Fahr.	Parts per Million. Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. Soluble	Oxygen Consumed at 90deg. Fahr. in 15 min.	Oxygen Consumed at 90deg. Fahr. in 4 hours.	Nitrogen as Nitrates.	Chlorine.	Colour Platinum Scale.	Total Solids.	Colour Units. Red.	Colour Units. Yellow.	Dissolved Oxygen per cent. of Saturation.	Bacteria per C.C.
May	—	.04	.298		1.85	3.75	Nil		50	110				
June	57.6	.051	.298		1.80	3.52	"		52					
July	57.	.051	.294	.272	1.49	2.95	"	33.3	41					
August.. ..	58.8	.029	.312	.258	1.40	2.72	"	32.7	37					
September ..	67.2	.033	.299	.259	1.18	2.50	"	32.5	32					
October ..	72.4	.042	.287	.269	1.36	2.64	"	36.2	32					
November ..	80.2	.053	.308	.265	1.18	2.26	"	37.4	21					130
December ..	78.7	.024	.336	.287	1.30	2.48	"	35.	21		0.6	2.6		150
1905.														
January ..	79.7	.014	.260	.250	1.36	2.76	"	37.1	20	108	0.8	3.3	75.6	
February ..	80.5	.042	.316	.270	1.64	3.57	"	34.5		111	1.2	4.7	86.5	1100
March.. ..	79.1	.017	.367	.266	2.14	3.99	"	33.7		114	1.2	4.4	89.2	600
April	74.7	.027	.262	.230	1.97	3.37	"	35.5		115	0.9	3.5	75.1	
May	67.3	.042	.313	.273	1.67	2.84	"	33.9			1.8	6.5		275
June	59.7	.03	.312	.302	1.48	2.78	"	33.4			1.8	6.0		*255 105
July	58.2	.01	.32	.32	1.58	3.15	"	35.7		112	1.3	4.6		*360

* Grown on Gelatine.

N.B.—The lagoon was occasionally tested for Nitrogen existing as Nitrites, but in no case was any found.

The turbidity of the water was in most cases under 5 parts per million; and on only one occasion was it more than 20 parts per million.

Appendix VIII.

MONTHLY AVERAGES OF PER CENTAGE REDUCTION IN ORGANIC MATTER, COLOUR AND BACTERIA, EFFECTED BY PLAIN SAND FILTRATION.

1905.	Temperature. Applied Water.	Temperature. Effluent.	Rate of Filtration. (Million gallons per acre per 24 hours.)	Ammonia. Free.	Ammonia. Albuminiod.	Oxygen Consumed at 90deg. Fahr. 15 minutes.	Oxygen Consumed at 90deg. Fahr. 4 hours.	Colour. (Lovibond Scale.) Red.	Colour. (Lovibond Scale.) Yellow.	Bacteria. (Grown on neutral Agar medium.)
(1904) December (start)	81	80	2.1	100	31.8	23.8	26.2	nil	nil	
(1905) January	80	77.5	2.0	71	48.8	26.1	36.3	71.5	48.1	
February	80.5	77.7	1.9	76.7	58.8	34.5	40.2	98.2	65.9	99.1
March	79.1	77.6	2.0	11.7	57.0	38.4	38.7	55.9	33.2	96.0
April	74.7	73.7	2.1	82.8	42.7	41.2	37.2	100.0	61.1	
May ..	67.3	65.5	2.4	75.3	51.4	30.7	30.0	88.7	67.4	98.2
June ..	59.7	56.1	2.1	97.6	44.5	30.0	18.4	85.7	69.7	96.0
July ..	58.2	54.5	2.3	100.0	57.8	31.6	32.7	92.0	67.0	99.0
Average from 23/12/04 to 12/7/05 ..			2.0	66.0	51.2	33.0	35.2	77.8	52.7	98.5

Appendix IX.

AVERAGE PER CENTAGE REDUCTION IN ORGANIC MATTER, COLOUR AND BACTERIA, EFFECTED BY THE VARIOUS TYPES OF FILTERS USED IN CONNECTION WITH THE EXPERIMENTAL PURIFICATION OF THE LAGOON WATER.

Type of Filter.	Period for which average reduction is calculated. Days.	Rate of Filtration (Million gallons per acre per 24 hours).	Average Percentage of Reduction. Albuminoid. Ammonia.	Oxygen. Consumed. 15 minutes.	Oxygen. Consumed. 4 hours.	Colour. Lovibond Tintometer Red.	Colour. Lovibond Tintometer Yellow.	Bacteria. (Grown on neutral Agar medium).
Morry Filter (sand & gravel)	139	2.1	54	40	39	93	67	91.8
Plain Sand Filter ..	183	2.0	53	33	36	93	66	98.5
Sand and Ashes ..	214	2.1	53.5	40	39	97	70	92.6
Machine Filter (Coagulants used)	80	104.0	56	57	41	—	—	—
Combination of Morry Filter and Plain Sand Filter	17	2.2	59	35	42	100	68	97.3
Intermittent Plain Sand Filter	62	2.1	58	43	43	99	66	74.2

Appendix X.

COMPARISON OF EFFLUENTS FROM A MECHANICAL FILTER AND AN INTERMITTENT PLAIN SAND FILTER, OBTAINED DURING PERIOD OF THREE MONTHS.

Average rate of filtration throughout period of test	Mechanical filter—104 million gallons per acre per 24 hours. Intermittent Sand Filter—2.23 million gallons per acre per 24 hours.

Average Results of Analyses Throughout Period of Test.

Parts per Million.	Albuminiod Ammonia.	Oxygen Consumed.			Colour Units.	
		Wankyln.	15 mins.	4 hours.	Red.	Yellow.
Machine Filter, Applied Water	.278	10.57	0.91	2.23	—	—
Effluent	.123	5.76	0.39	1.32	—	—
Sand Filter, Applied Water	.322	—	2.00	3.62	1.1	4.1
Effluent	.136	—	1.13	2.08	.01	1.4

COMPARISON OF AVERAGE PER CENTAGE REDUCTION IN ORGANIC MATTER EFFECTED BY MACHINE FILTER AND INTERMITTENT PLAIN SAND FILTER.

Per cent. Reduction.	Albuminoid Ammonia.	Oxygen Consumed.			Colour Units.	
		Wanklyn.	15 mins.	4 hours.	Red.	Yellow.
Machine Filter	55.7	45.5	57.1	40.8	—	—
Sand Filter	57.7	—	43.5	42.5	99.1	65.8

Appendix XI.

ANALYSES OF SAMPLE OF LAGOON WATER COMPARED WITH FILTRATES FROM ANDERSON'S PROCESS.

Parts per Million.	Lagoon Water.	4 Minutes contact with Cast Iron Borings, Aeration, 48 hours Settlement, and Filtration through two thicknesses of Berzelius Filter Paper.	4 minutes contact with Cast Iron Borings, Aeration, 12 hours Settlement, and Filtration through three thicknesses of Berzelius Filter Paper.
Free Ammonia	.01	.04	.10
Albuminoid Ammonia	.32	.12	.207
Oxygen Consumed in 15 Minutes ..	1.58	.49	.88
Oxygen consumed in 4 hours ..	3.15	1.08	1.77
Iron (as Fe.) ..	.57	——	.055
Nitrogen as Nitrates ..	nil	nil	nil
Turbidity ..	nil	nil	very faint opalescence
Colour—Lovibond—Units.			
Red	1.3	nil	nil
Yellow	4.6	0.3	0.5
Odour	d'cd'd sw'py	nil	nil

Appendix XII.

BIOLOGICAL CONTENTS OF LAGOON WATER AT SURFACE NEAR OUTLET.

Date.	Depth.	Total Organisms per C.C. (not Bacteria).	Standard Units per C.C.
13/8/04	Samples collected one foot below surface	240	——
10/10/04		264	——
26/1/05		960	——
1/2/05		1040	——
8/2/05		1208	3175
16/2/05		1080	1426
21/2/05		528	*3425
22/2/05		736	*3008
3/3/05		596	1302
15/3/05		344	353
17/3/05		2960	*14908
4/4/05		840	1222
27/4/05		152	198

*Samples marked thus contained some of the floating scum from the surface of the lagoon.

Appendix XIII.

SHADE TEMPERATURE OF THE ATMOSPHERE AT THE LAGOON.

(Degrees Fahrenheit).

Period.	Average Daily Mean Temperature.
For month of July, 1904	55.3
August, 1904	56.1
September, 1904	61.7
October, 1904	68.7
November, 1904	72.7
December, 1904	75.8
January, 1905..	79.5
February, 1905	78.3
March, 1905	74.9
April, 1905	71.2
May, 1905	61.0
June, 1905	55.8
Average Daily Mean Temperature for 12 months ..	67.0

EXTREME TEMPERATURES FOR ABOVE PERIOD.

(Degrees Fahrenheit)

Date.		
15th June, 1905	Lowest Minimum Temperature ..	32.0
15th June, 1905	Lowest Daily Mean Temperature ..	44.5
3rd January, 1905	Highest Maximum Temperature ..	113.0
5th January, 1905	Highest Daily Mean Temperature ..	93.0

NOTE.—The prevailing organism in the reservoir is described in this paper as *Protococcus*, because the dimensions of its cells correspond more closely with the dimensions of Protococcus infusionum—*Rabenhorst* (aquatic form)—than with those of any other similar organism; the method of multiplication, by cell division, is also similar. In other respects, however, it agrees with descriptions of Clathrocystis æruginosa, *Henfrey*; but I have never observed the thallus in clathrate form, it having been always either saccate or broken up into small fragments. The diameter of the cells is given for C. æruginosa as 2.5—3.5 μ, whilst the cells of our organism vary from 4.5—10 μ. Like C. æruginosa, it appears on the surface of the reservoir "as a bright green scum, sometimes glaucous, presenting to the naked eye a finely granular appearance, and when dried appearing like a crust of verdigris." *Vide Cooke's British Freshwater Algae.* Professor Moebius found the organism —C. æruginosa—associated with Peridinia in water brought by pipes from this reservoir, and collected by Dr. Thos. L. Bancroft. *Vide Contributions to Queensland Flora, by F. M. Bailey, F.L.S., 1893.* The organism under discussion is always found associated with Peridinia, Anabœna, etc.

H.W.